Three-Dimensional Characterization of Atmospheric Gravity Waves Using Thermal Radiance Imagery from AIRS and AMSU-A

EARTH SYSTEM SCIENCE RESEARCH USING DATA AND PRODUCTS FROM TERRA, AQUA, AND ACRIMSAT SATELLITES

NASA ROSES – NNH06ZDA001N Program Element A.15 **Project 06-EOS/06-0203**

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Integrating Separate AMSU-A and AIRS Research on Stratospheric Gravity Waves

AMSU-A-only Research

Eckermann and Wu, ACP, 2006

Eckermann et al., ACP, 2006

AIRS-only Research

Alexander and Barnet, JAS, 2007

Combined Analysis of Synchronous AIRS/AMSU-A Radiances from Aqua for Gravity Waves

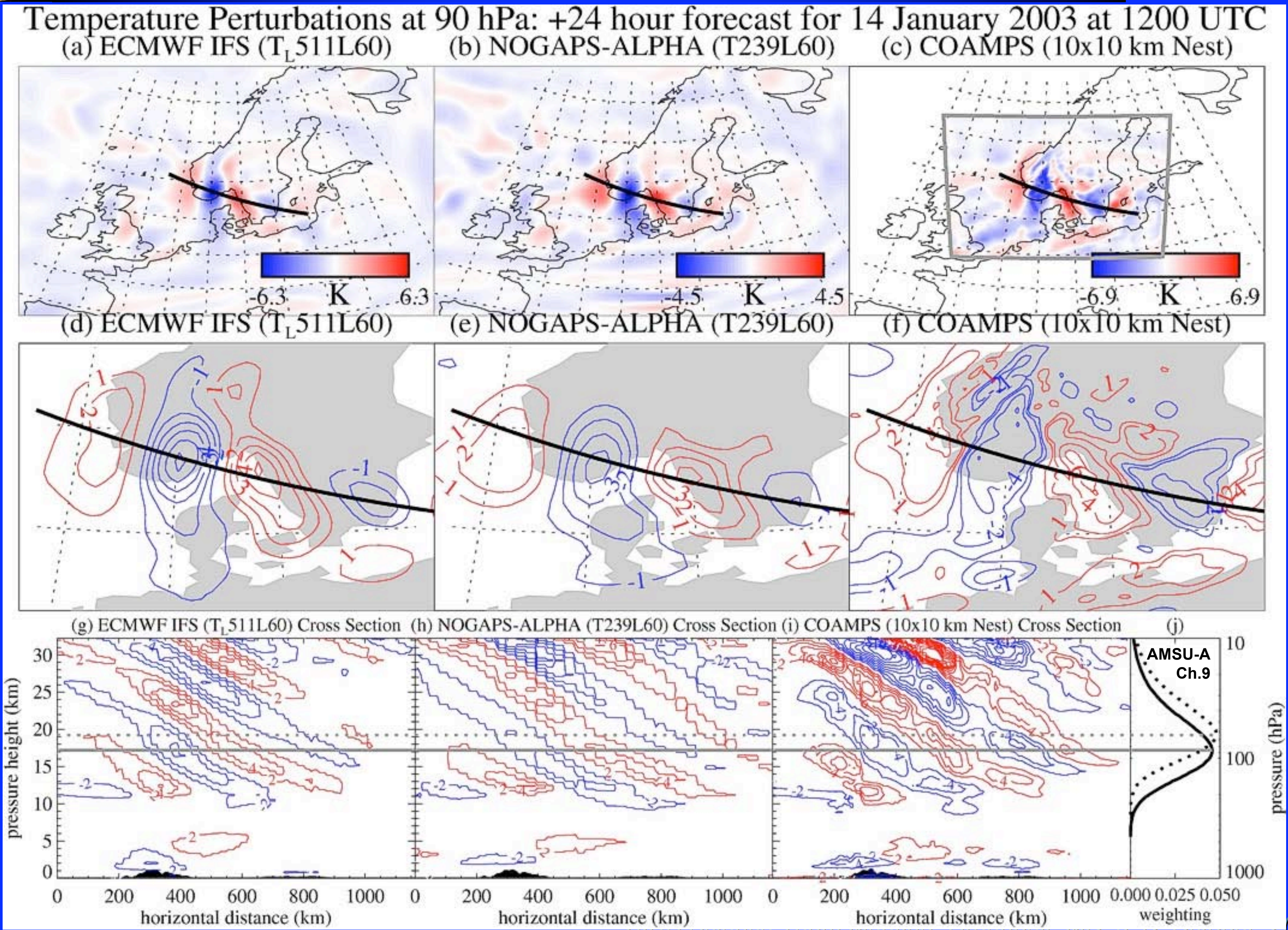
Analysis of Gravity Waves in AIRS/AMSU/HSB (AAH) Temperature Retrievals

SCIENCE GOAL: Global 3D Characterizations of Stratospheric Gravity Waves for Constraining Subgrid-scale Parameterizations of Large-scale Gravity Wave Effects in NWP & Climate Models

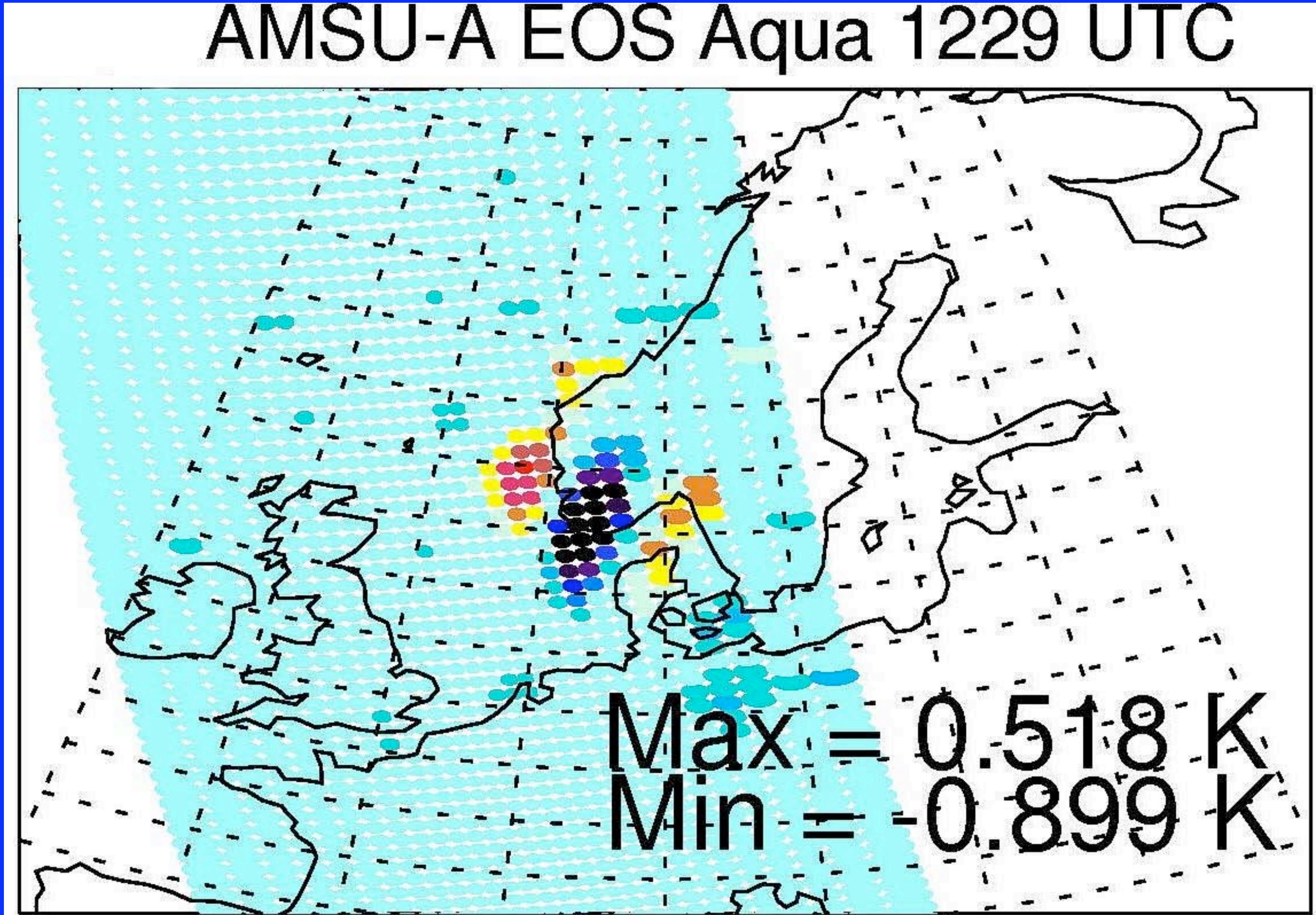
Illustrate Overall Science Goals in Application to One Orographic Gravity Wave Event

1. Are Gravity Waves Resolved in AMSU-A Thermal Radiances?

ECMWF IFS, NOGAPS-ALPHA and COAMPS®
Hindcast *T'* Fields: 14 Jan 2003 1200 UTC



AMSU-A Channel 9 Brightness Temperature Perturbations (T'$_B$)

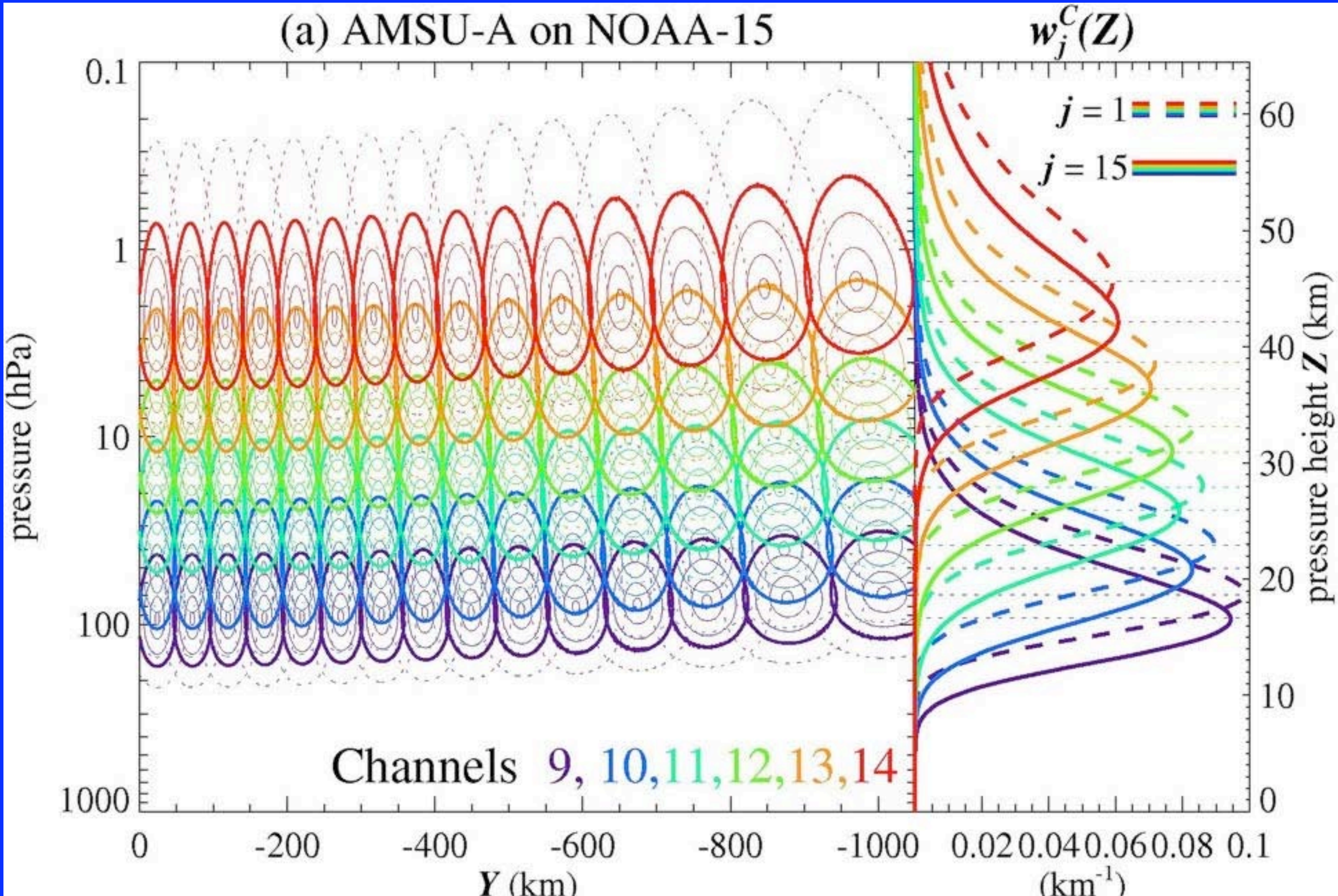


Are Gravity Waves Resolved in AMSU-A Thermal Radiances?

Looks Promising…

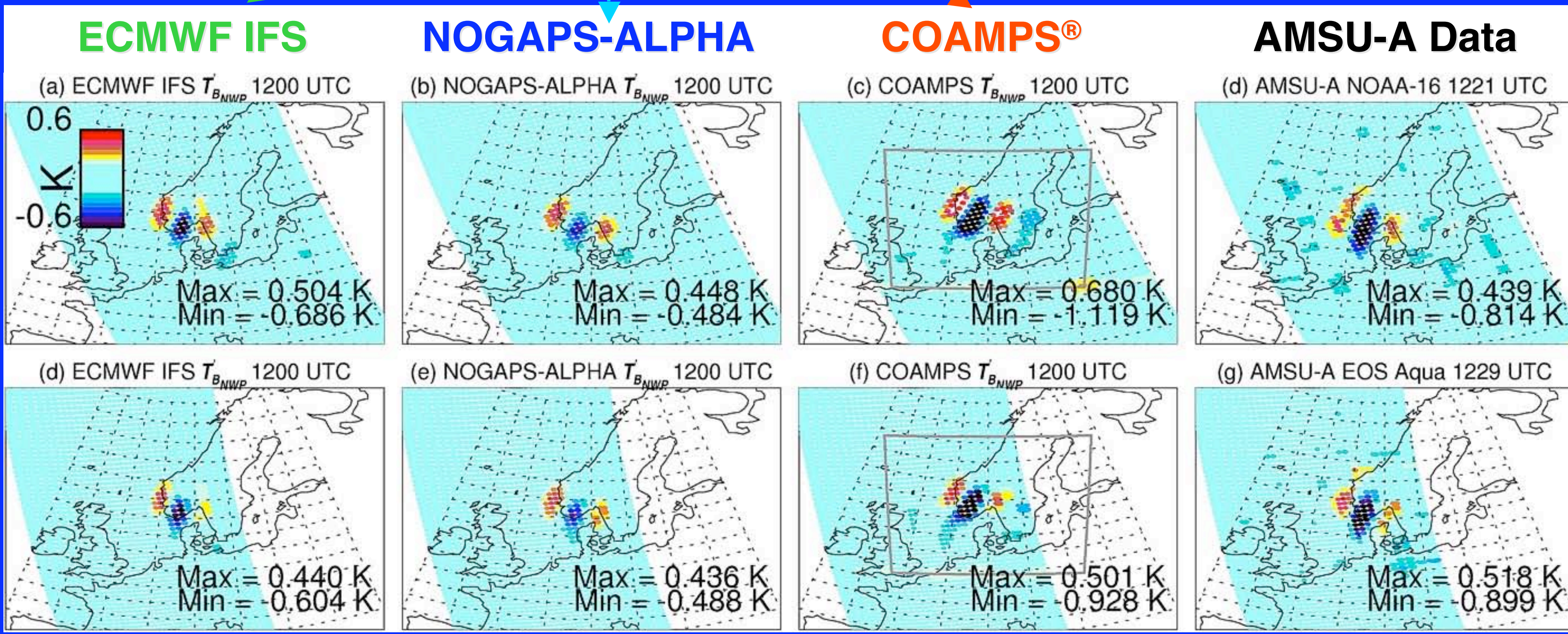
→ Validate Using 3D Forward Model

Extension to Other AMSU-A Channels



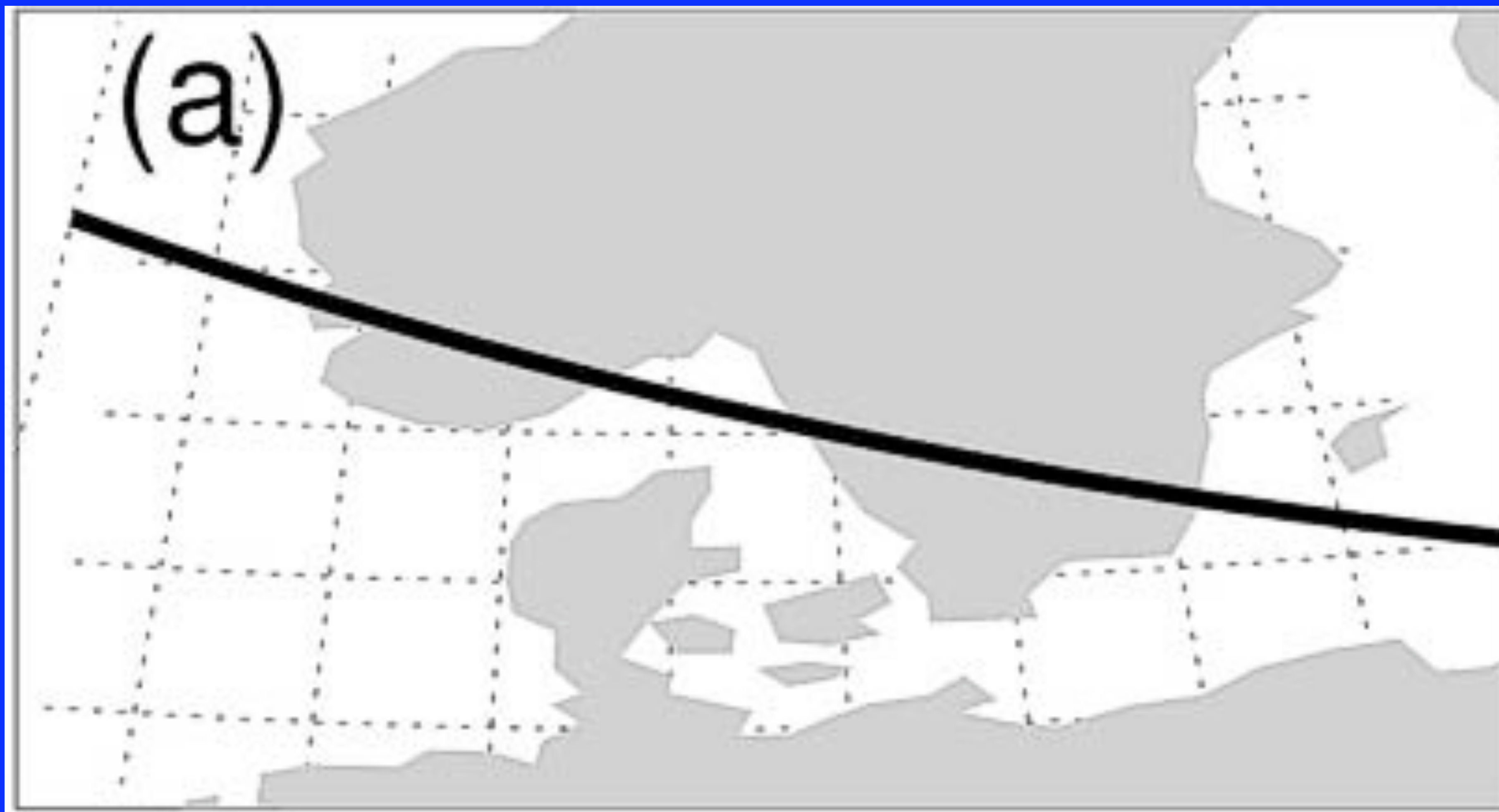
Model-Data Comparison by 3D Forward Modeling
(Simulate AMSU-A Measurement of Modeled T(X,Y,Z) Fields)

$$T_B(X_j,Y_j,Z_j)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{0}^{Z_{sat}} W_j(X-X_j,Y-Y_j,Z-Z_j)T(X,Y,Z)dXdYdZ$$



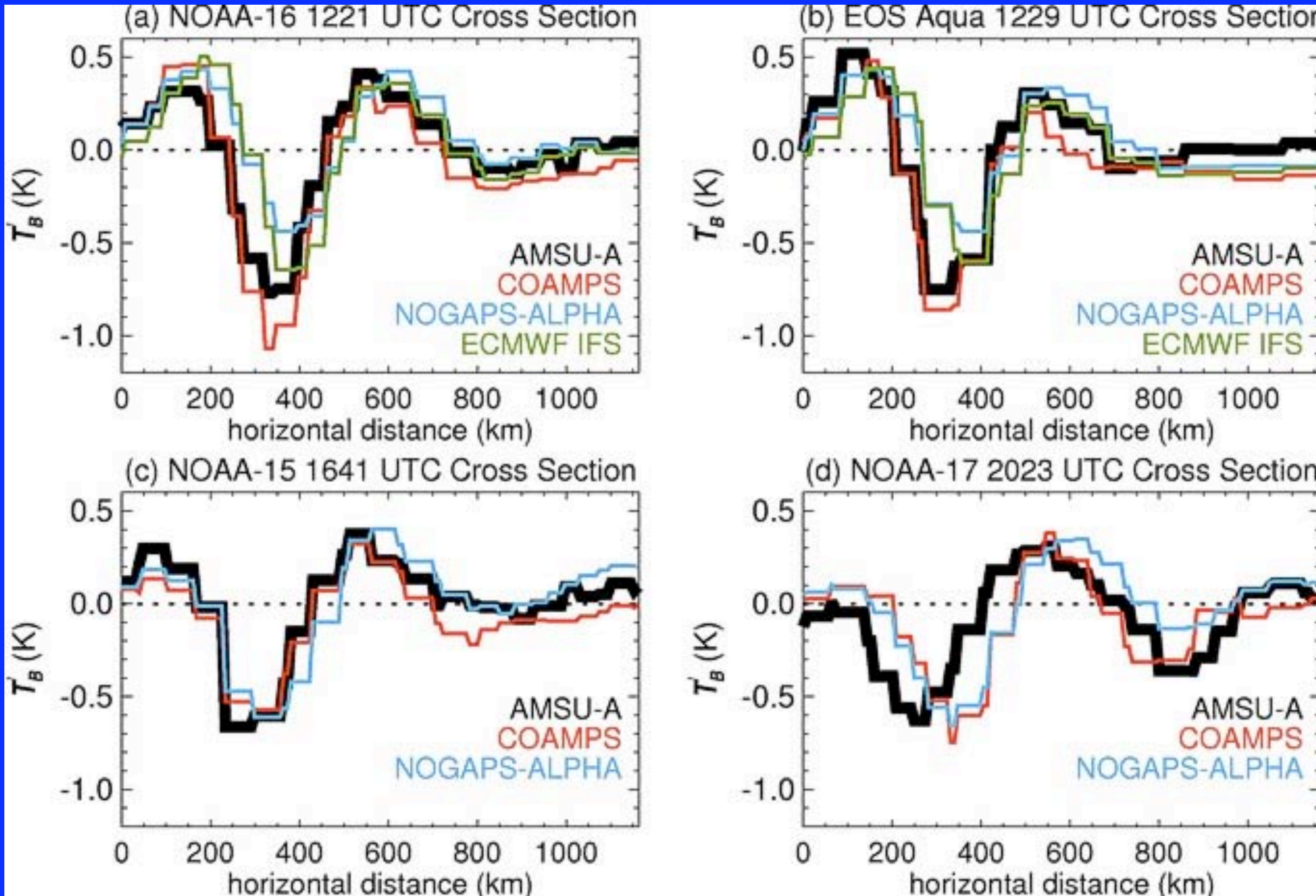
<u>Channel 9</u>: 60-90 hPa

Cross Sectional Comparisons



Point-by-Point Comparisons

Science Team Meeting
October 9-12



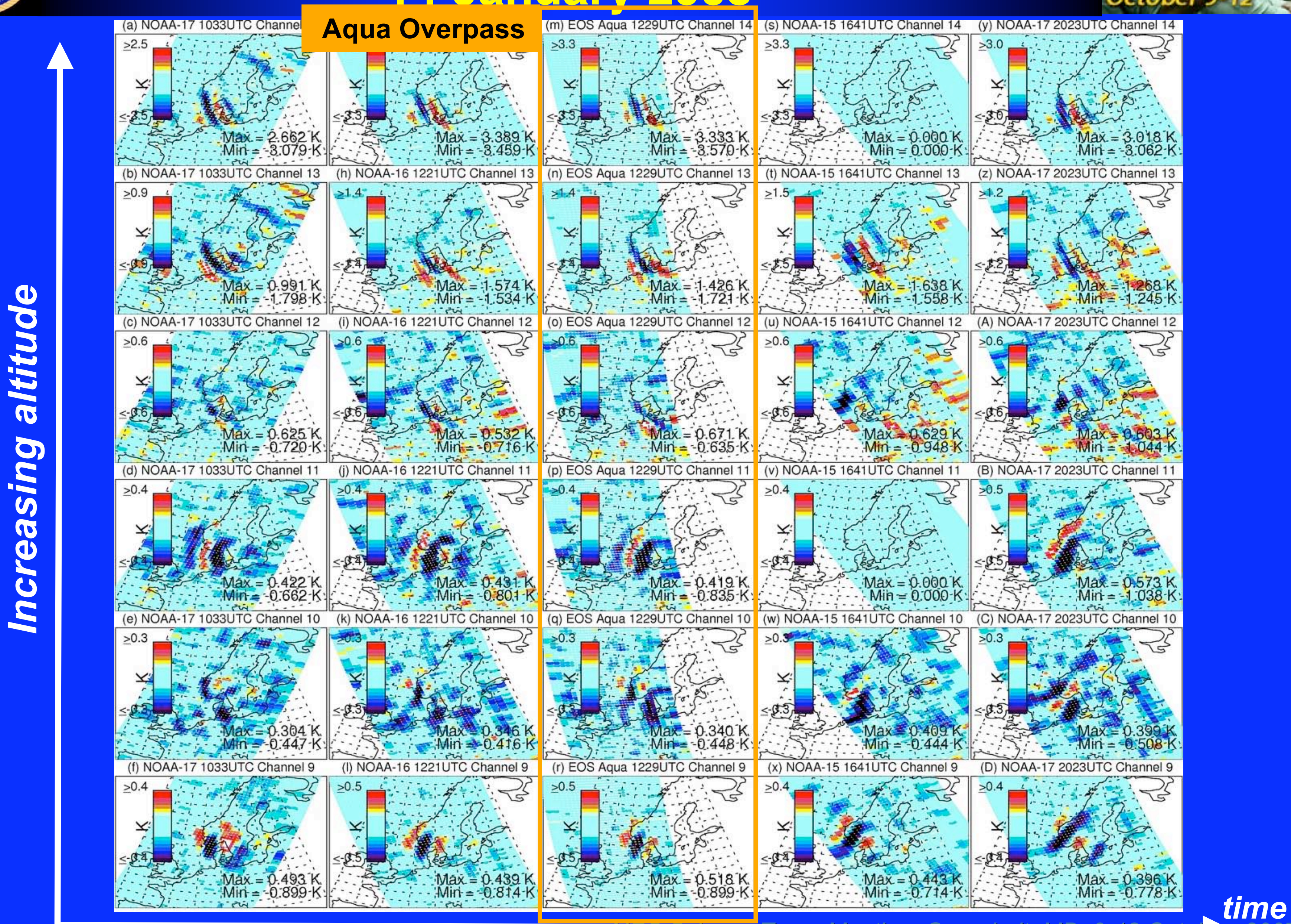
Are Gravity Waves Resolved in AMSU-A Thermal Radiances?

Yes!

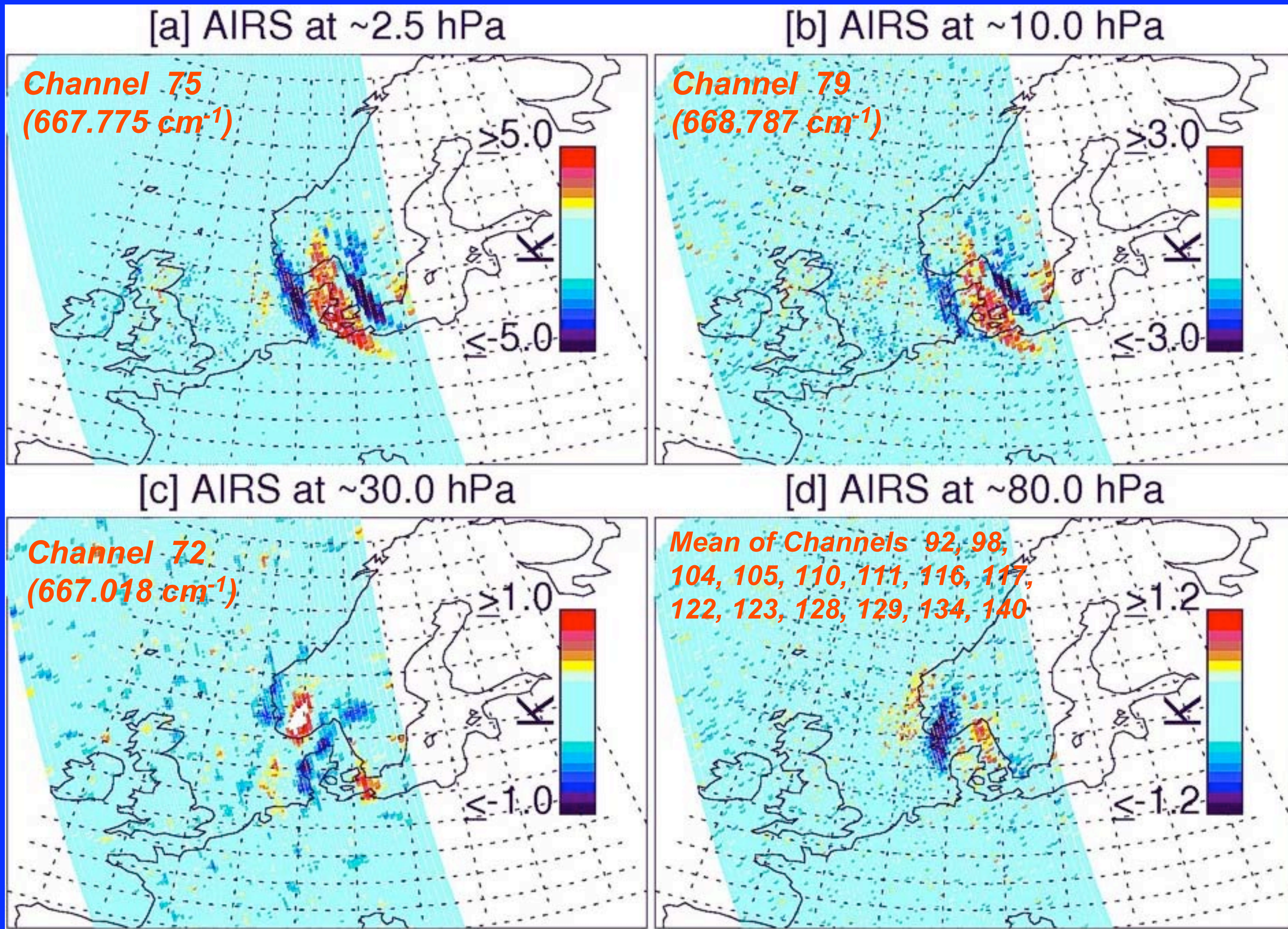
(but not as well as in AIRS radiances…)

What about other AMSU and AIRS Channels?

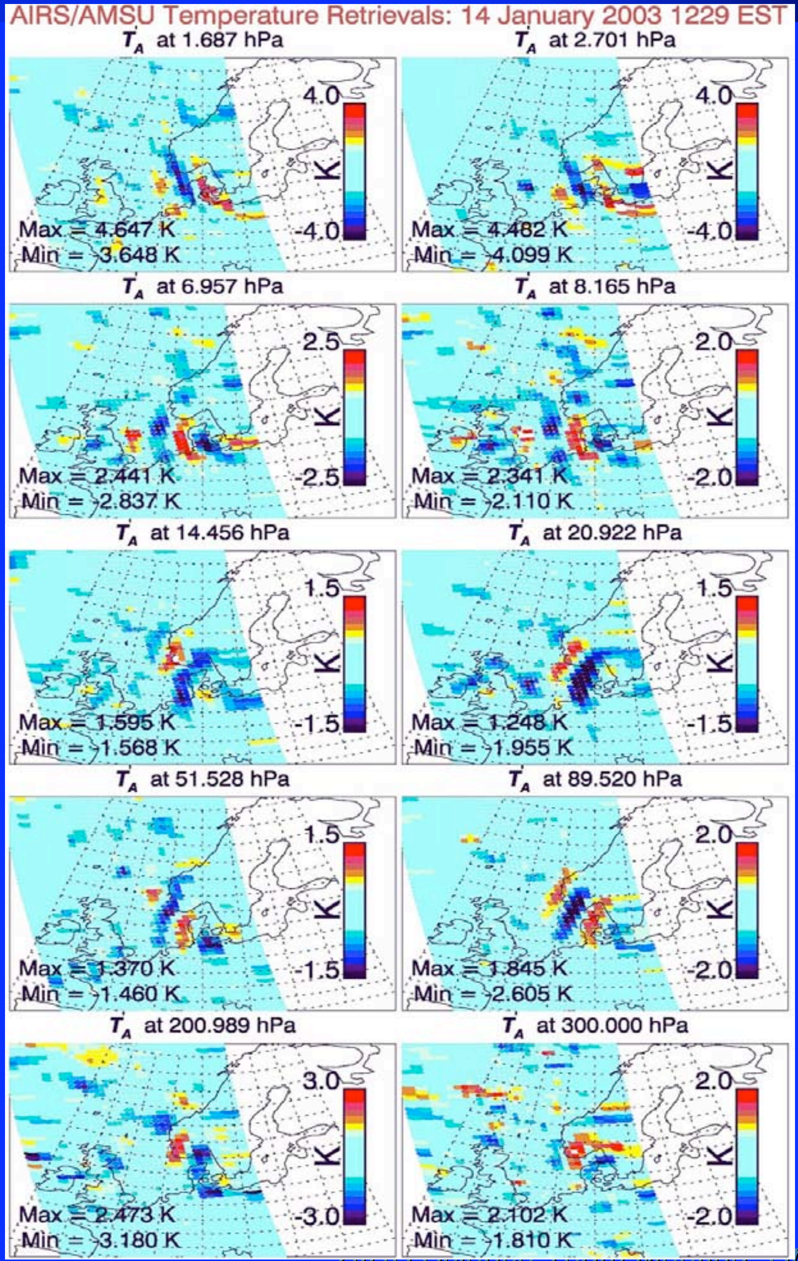
AMSU-A Channels 9-14 Radiances: 14 January 2003



Multichannel AIRS Radiances: 14 Jan 2003



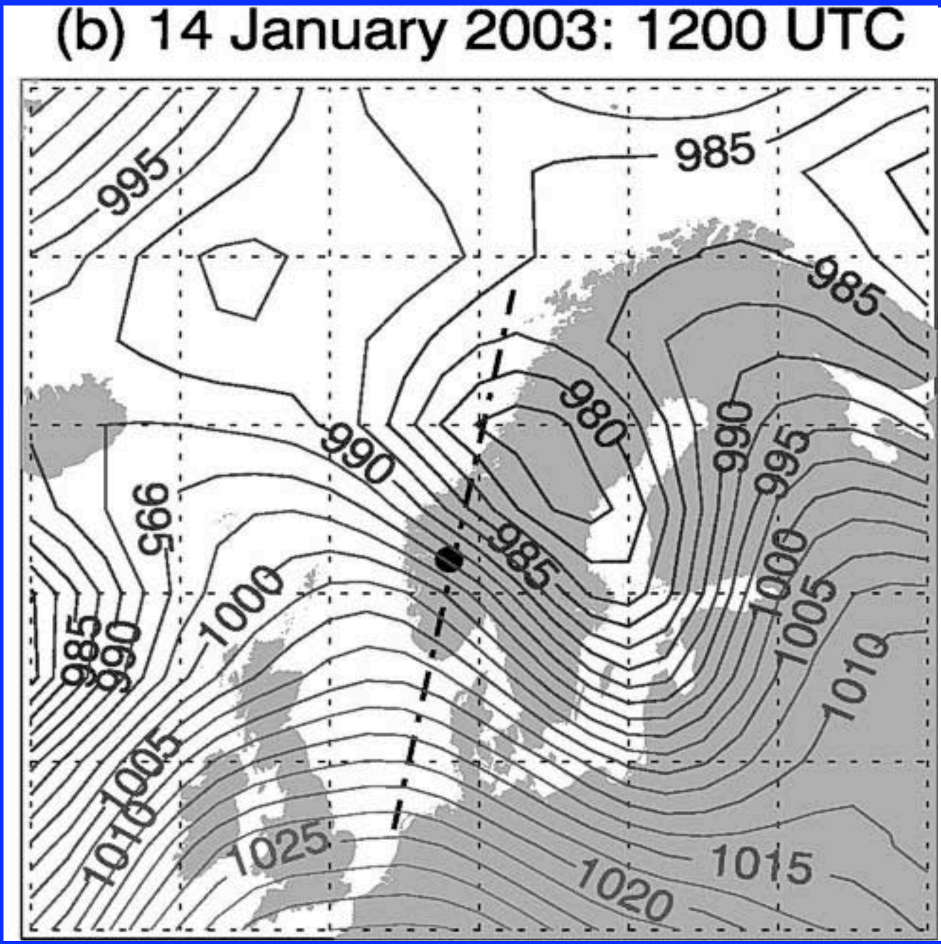
AIRS/AMSU Temperature Retrievals

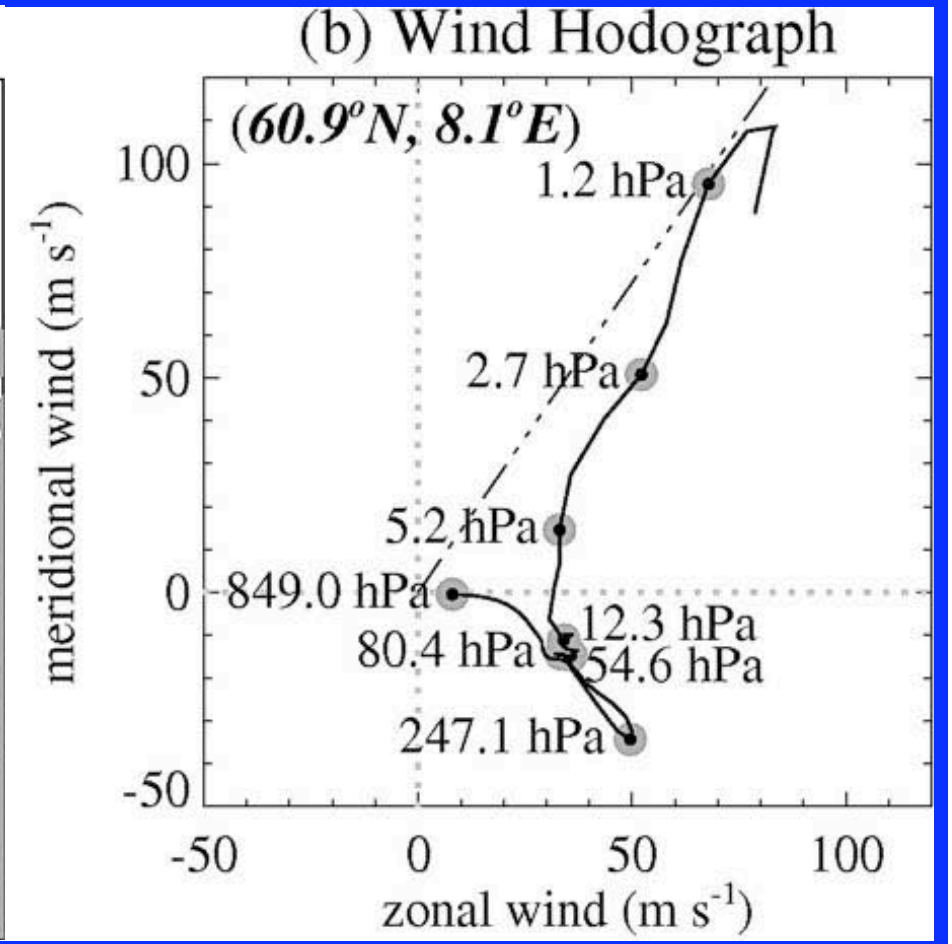


New Science from This Mountain Wave Observation

What Causes the Abrupt Phase Line Orientation Change at the Channel 11-12 Interface at ~10 hPa?

Wind Speeds and Directions

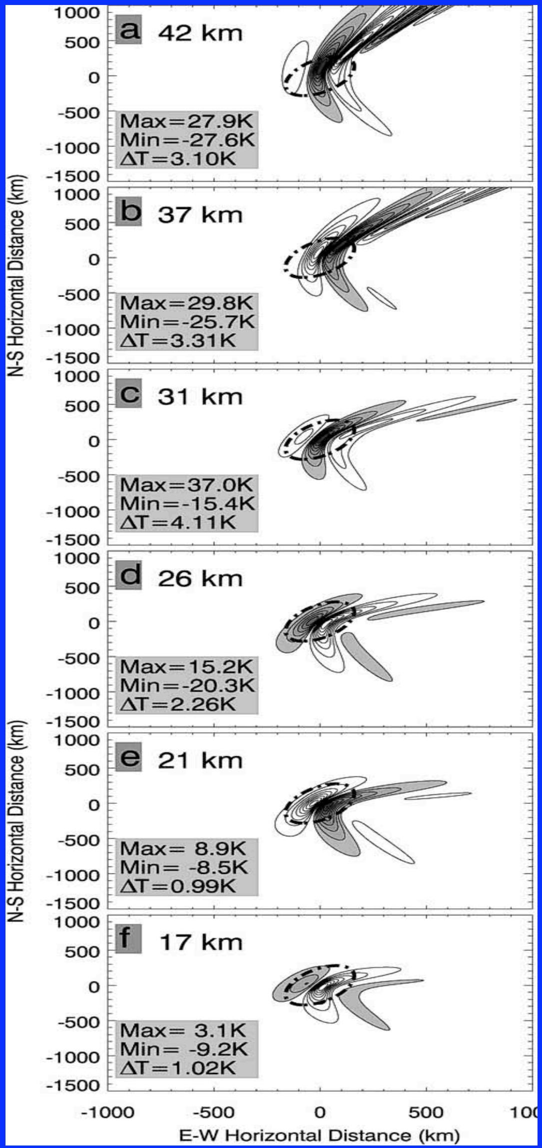


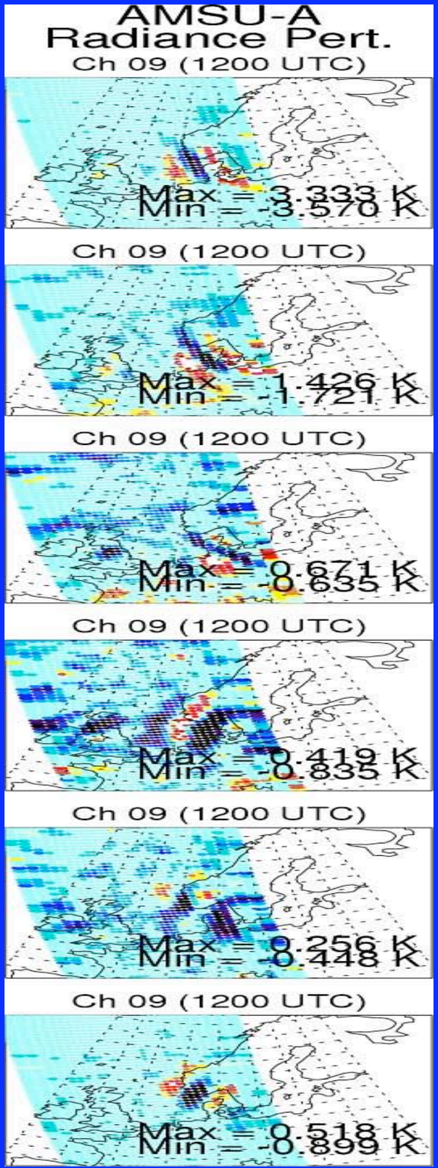


Mountain Wave Modeling

Science Team Meeting October 9-12

Fourier-Ray *T′* solutions for 3D elliptical obstacle

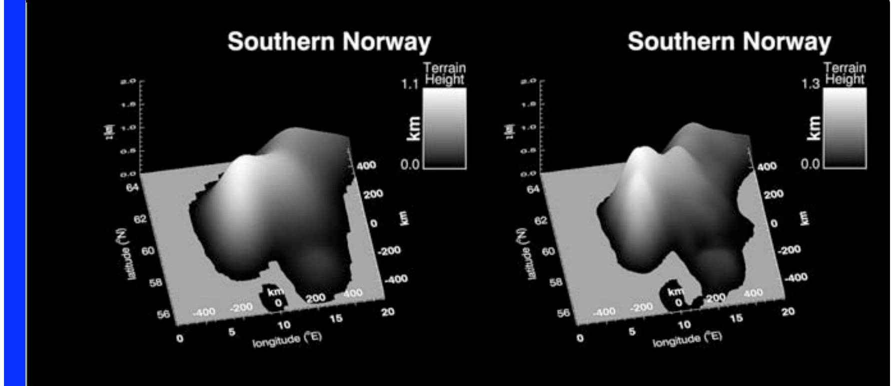


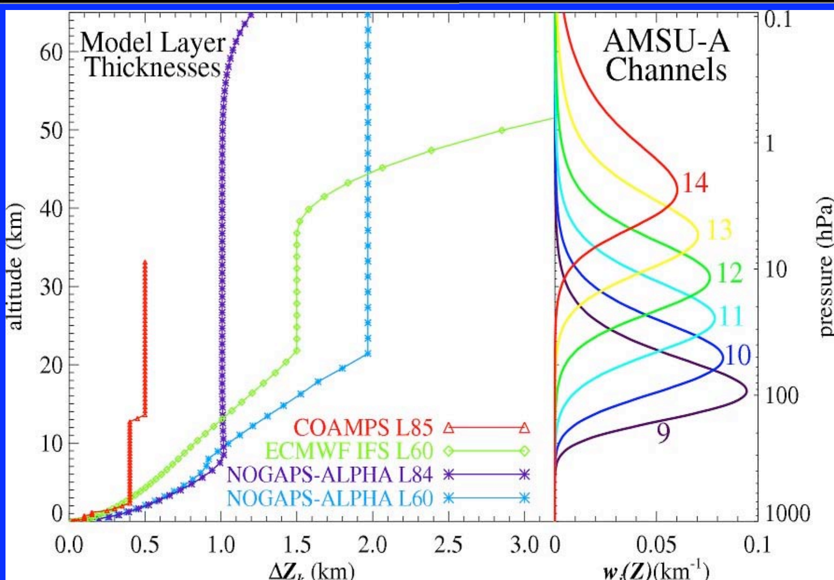


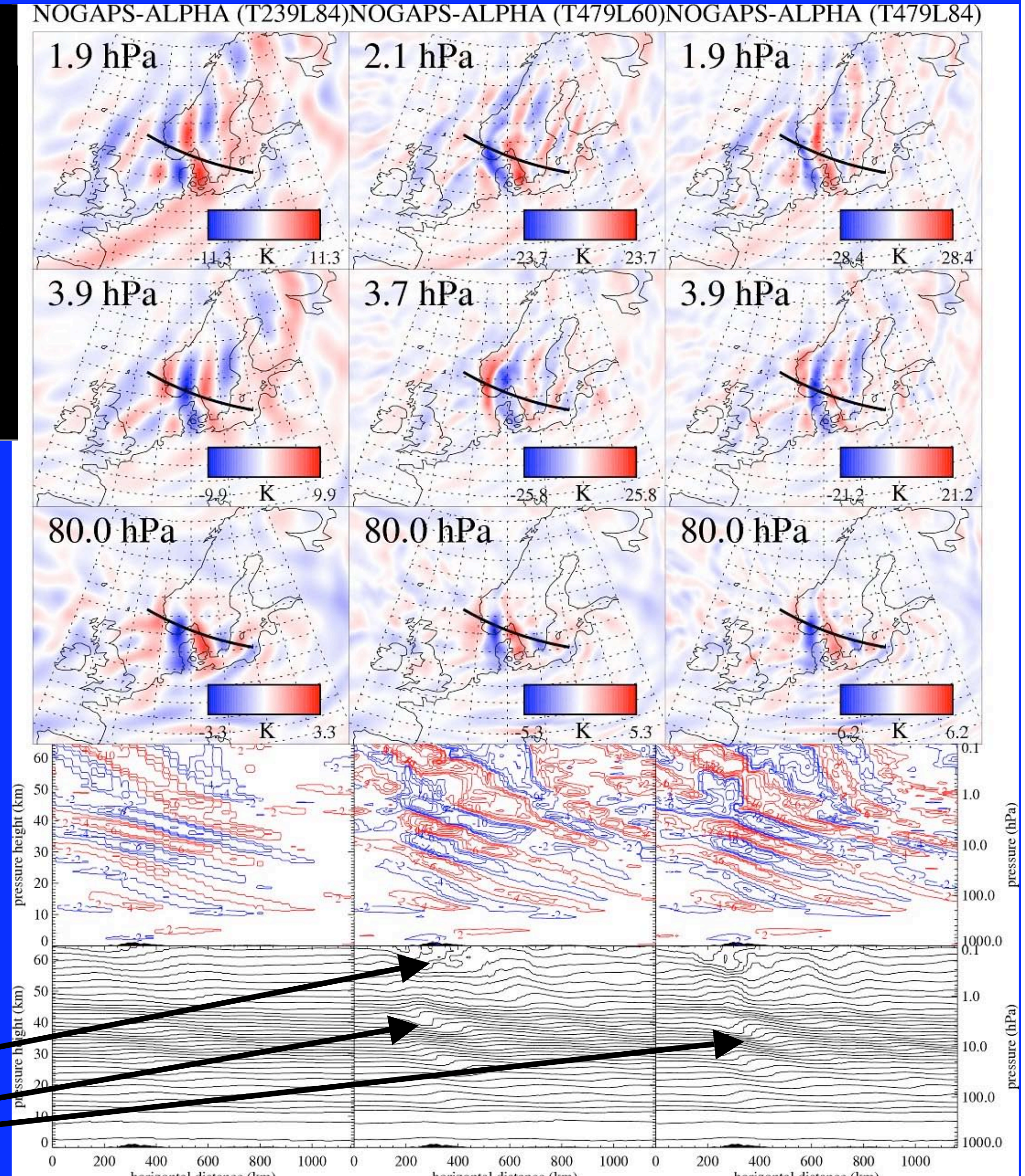
Validation of High-Resolution High-Altitude NWP Models

High-Resolution NWP Model Runs

NOGAPS T239 **NOGAPS T479**

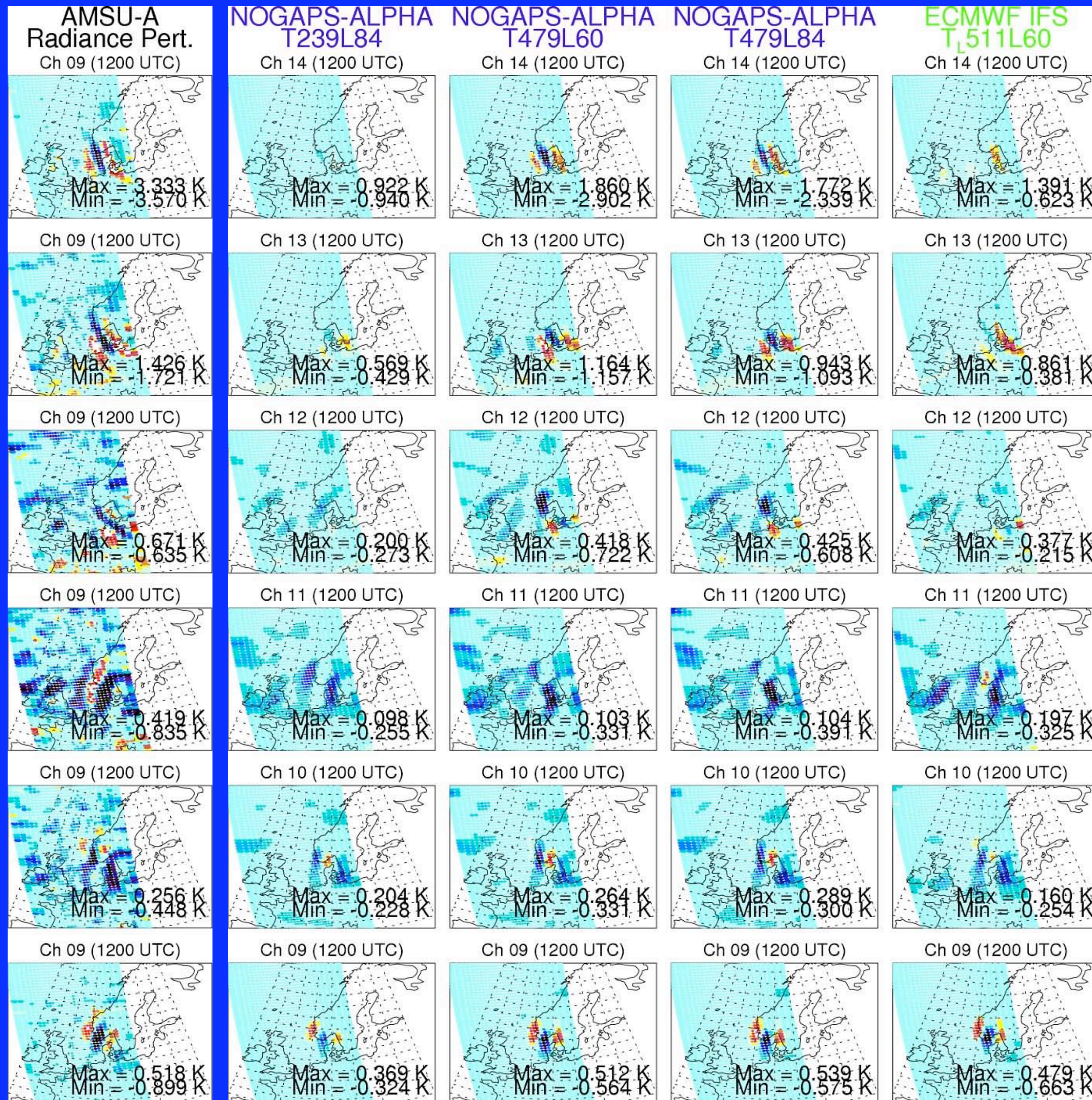






explicitly-resolved mountain wave breaking and drag

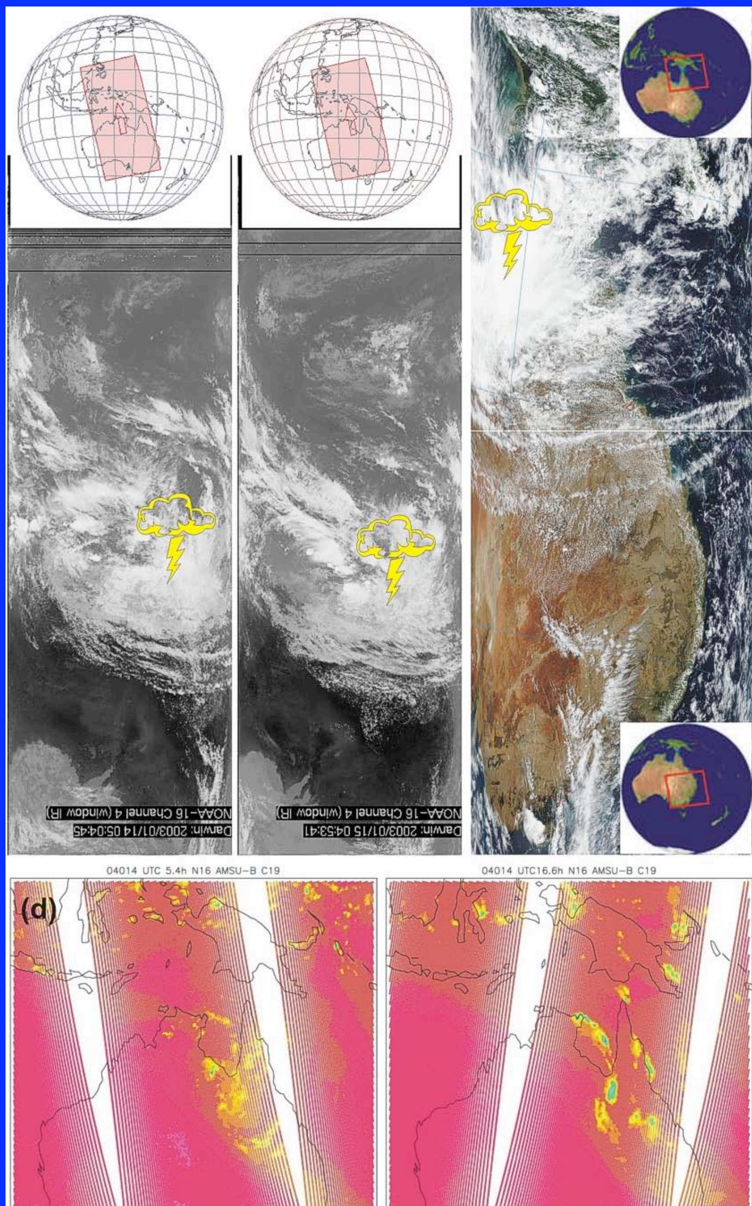
NWP Model Validation using AMSU-A

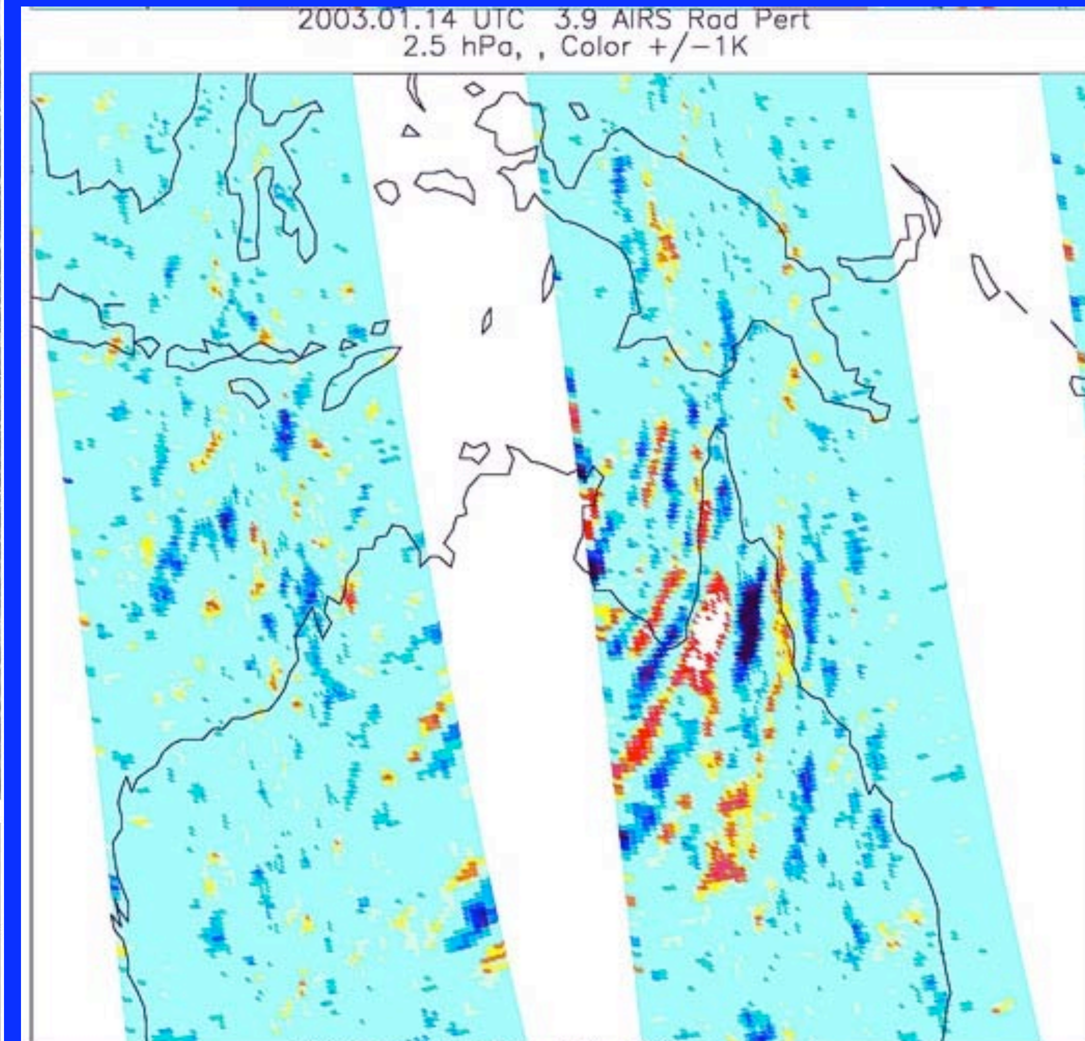


Fully Integrated AIRS/AMSU Analysis of a Variety of Gravity Wave Events

- *Collaborative characterization of global gravity wave properties, sources, and momentum fluxes using all the tools we have available in the AIRS/AMSU kit….*

Stratospheric Gravity Waves Generated by Deep Tropical Convection: 14 Jan 2003





The End

Thanks!

Backup Slides Follow…

For More Details, see….

Eckermann, S. D., D. L. Wu, J. D. Doyle, L. Coy, J. P. McCormack, A. Stephens, B. N. Lawrence, and T. F. Hogan, Imaging gravity waves in lower stratospheric AMSU-A radiances, ***SPARC Newsletter*, *26*, 30-33, 2006**.

Eckermann, S. D., and D. L. Wu, Imaging gravity waves in lower stratospheric AMSU-A radiances, Part 1: Simple forward model, ***Atmos. Chem. Phys.*, *6*, 3325-3341, 2006**.

Eckermann, S. D., D. L. Wu, J. D. Doyle, J. F. Burris, T. J. McGee, C. A. Hostetler, L. Coy, B. N. Lawrence, A. Stephens, J. P. McCormack, and T. F. Hogan, Imaging gravity waves in lower stratospheric AMSU-A radiances, Part 2: Validation case study, ***Atmos. Chem. Phys.*, *6*, 3343-3362, 2006**.

Eckermann, S. D., J. Ma, D. L. Wu, and D. Broutman, A three-dimensional mountain wave imaged in satellite radiance throughout the stratosphere: Evidence of the effects of directional wind shear, ***Quart. J. Roy. Meteorol. Soc.*, (in press), 2007**.

SOLVE-II DC-8 Flight of 14 January 2003

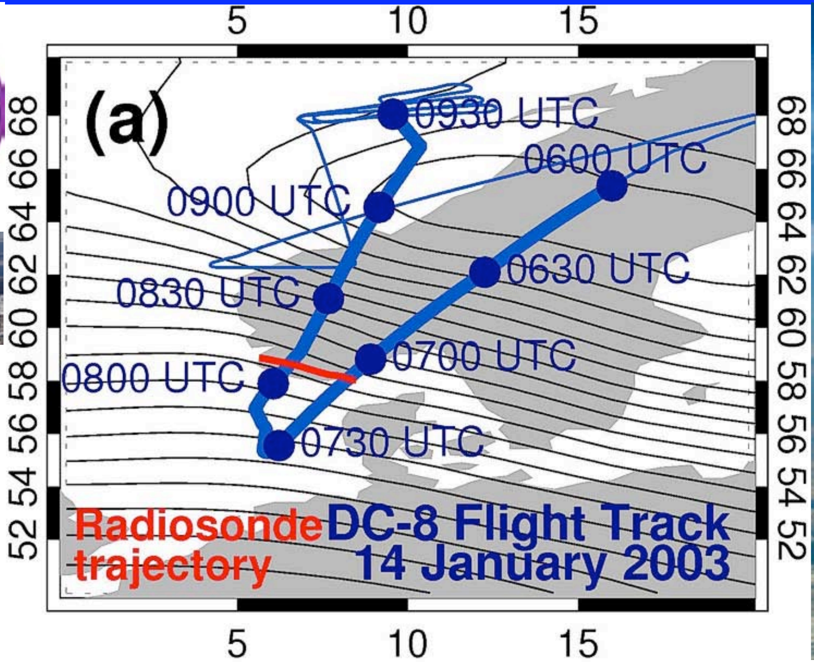
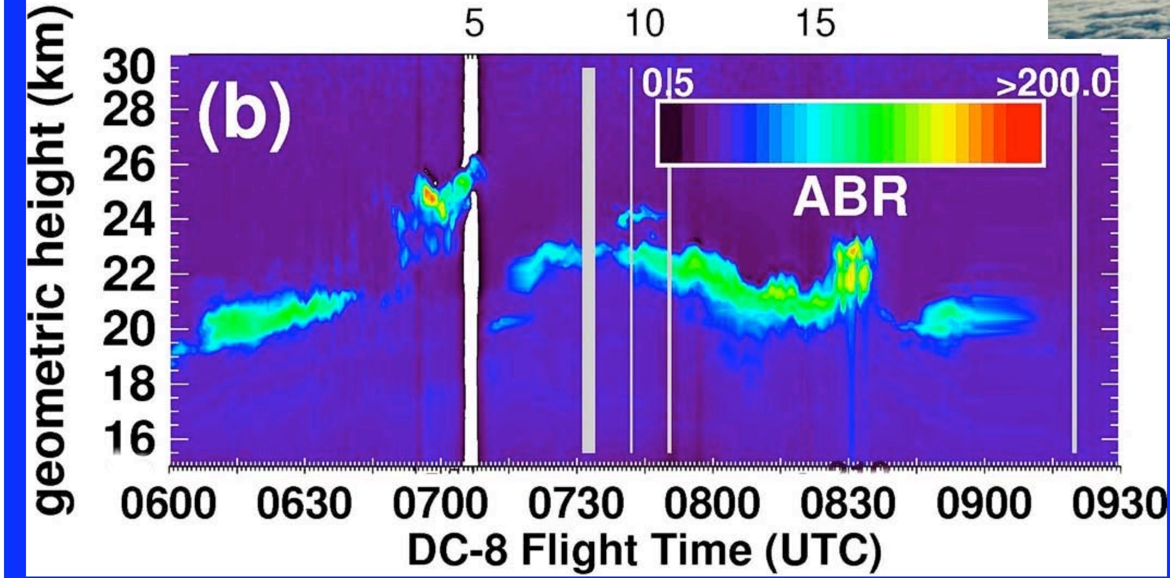


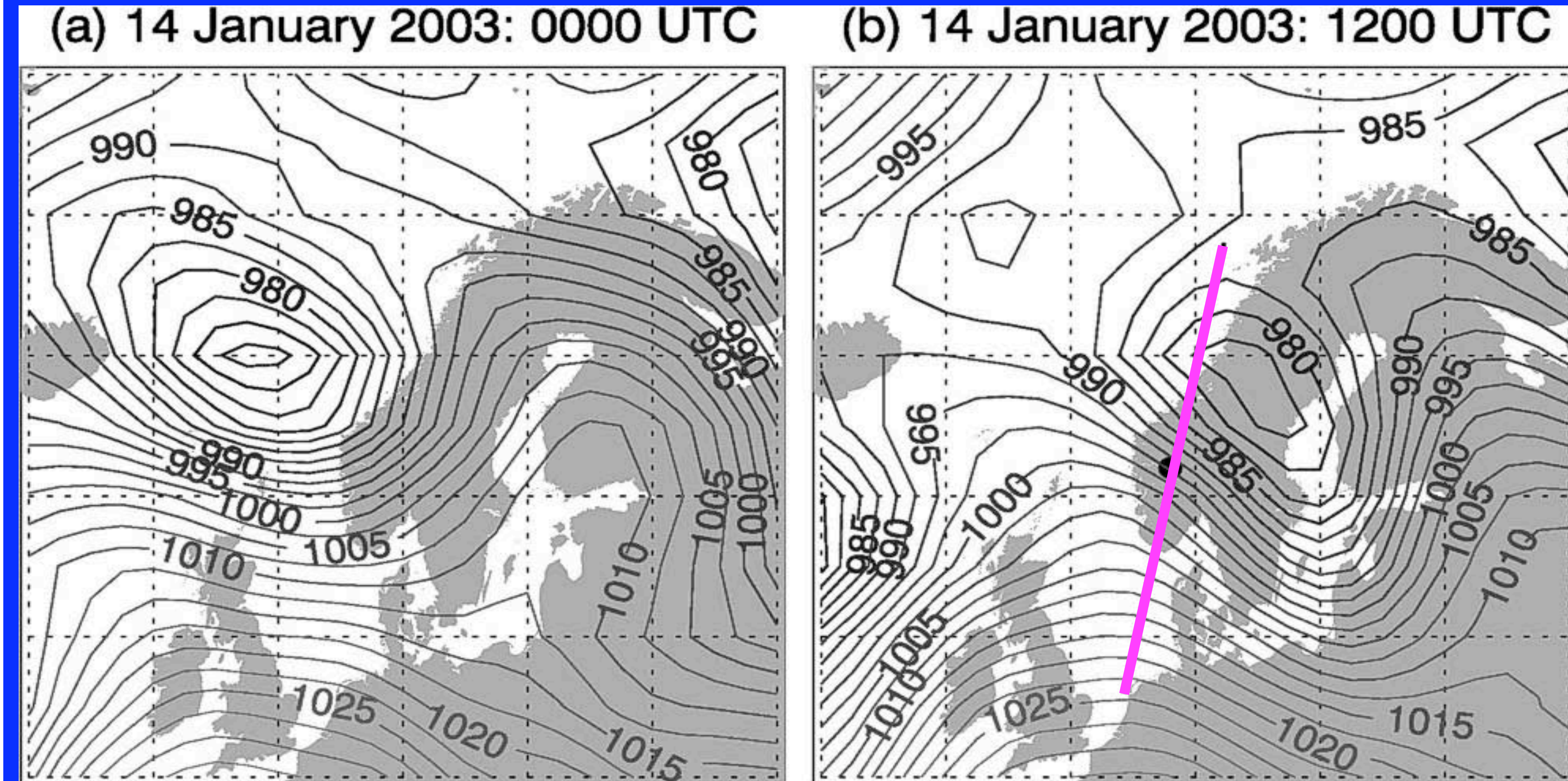
Photo from the NASA DC-8 of mountain wave PSCs over south-western Scandinavia on 14 January 2003 (*courtesy Paul Newman, NASA GSFC*)



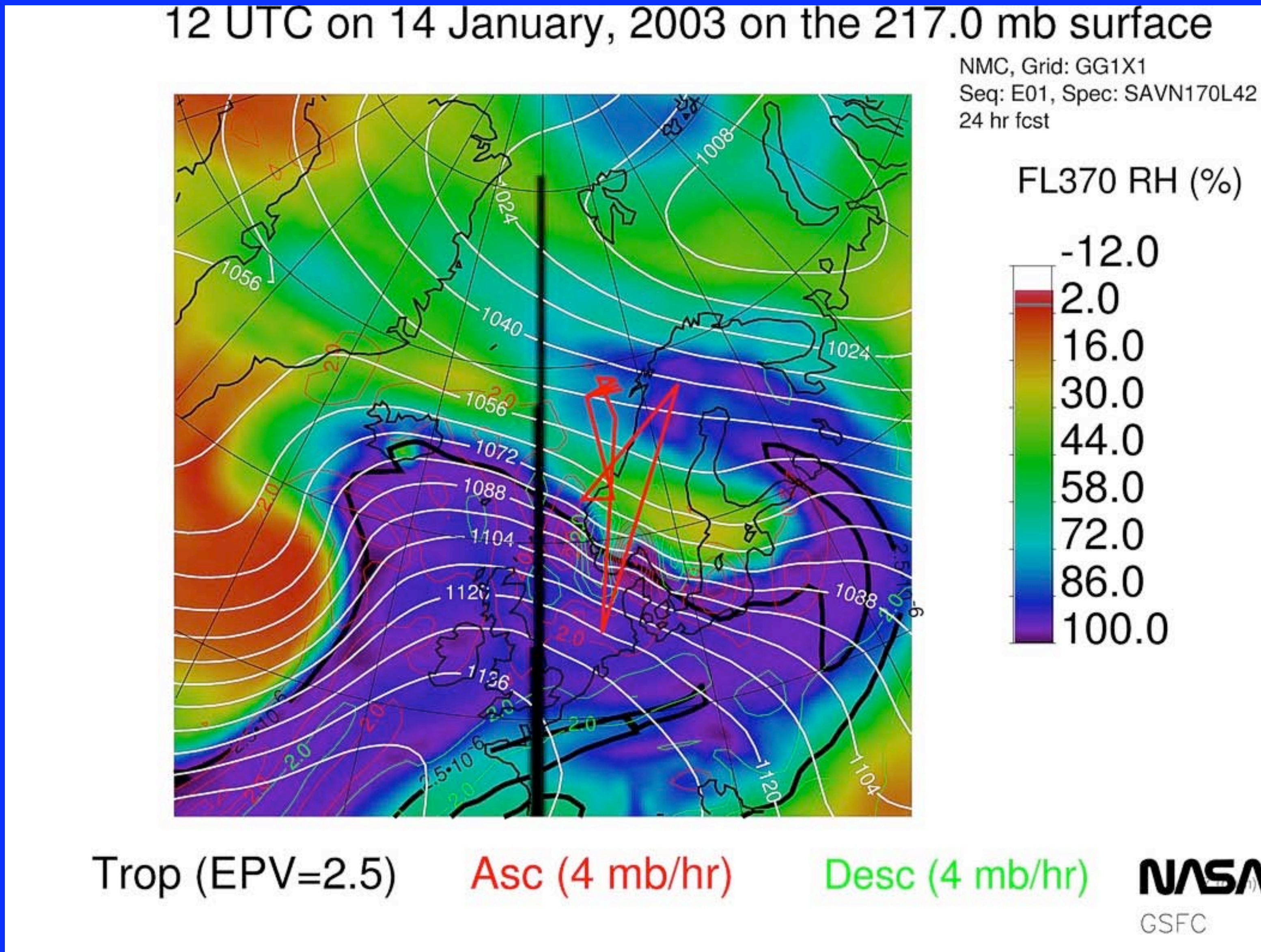
Mountain Wave PSCs

Aerosol Backscatter Coefficients (ABR) from NASA Langley Lidar on DC-8

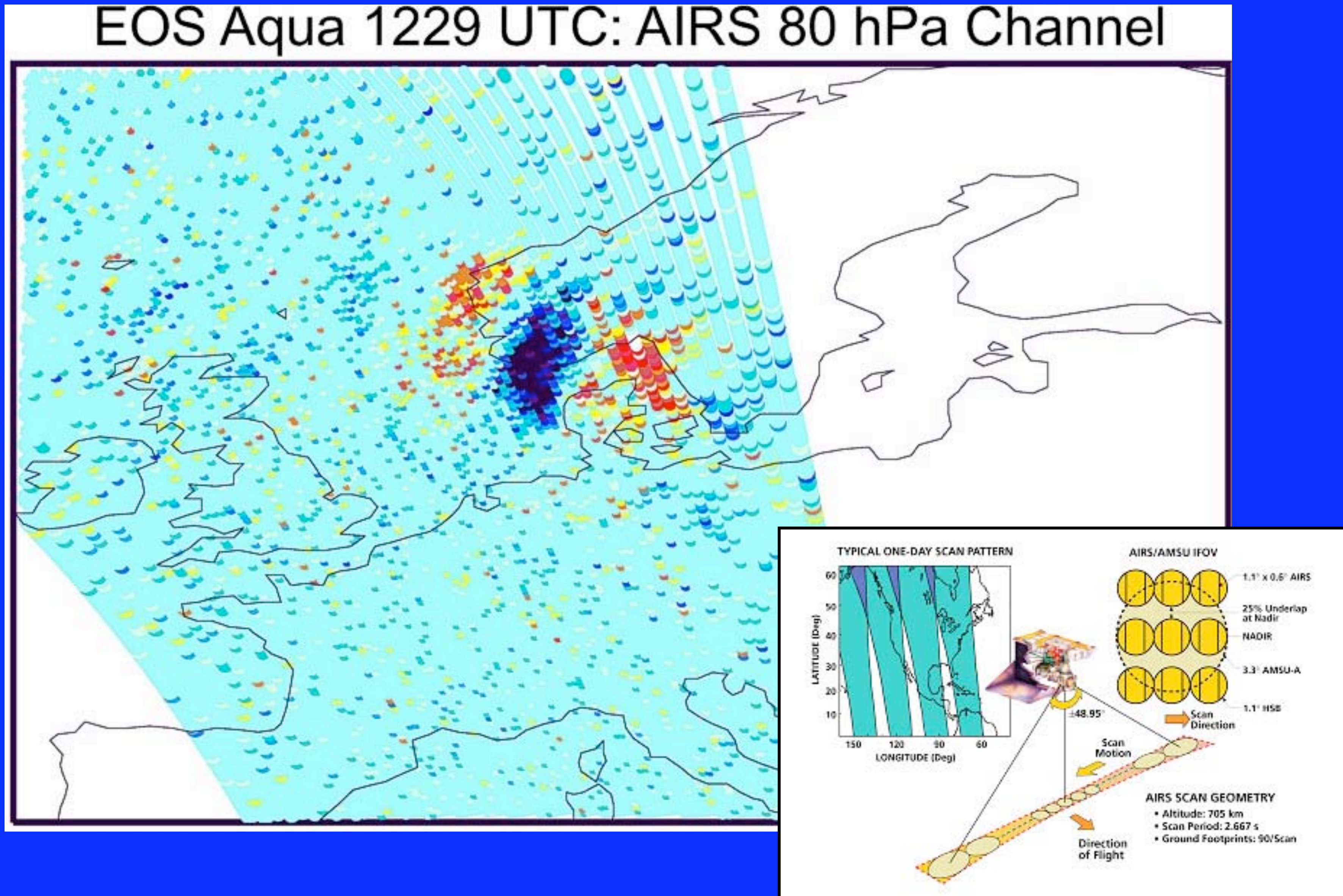
Mean Sea Level Pressures



High Tropopause with High Relative Humdity



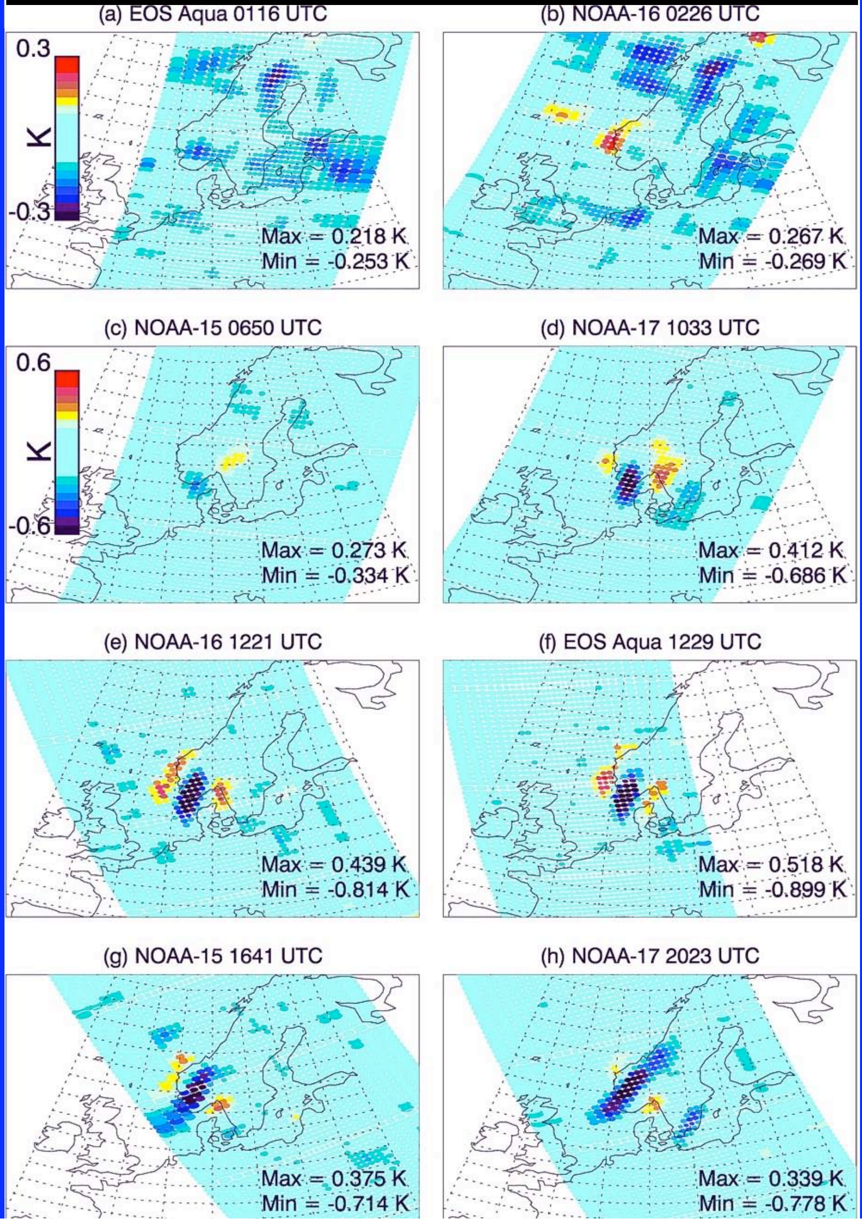
AIRS Result for 14 Jan 2003



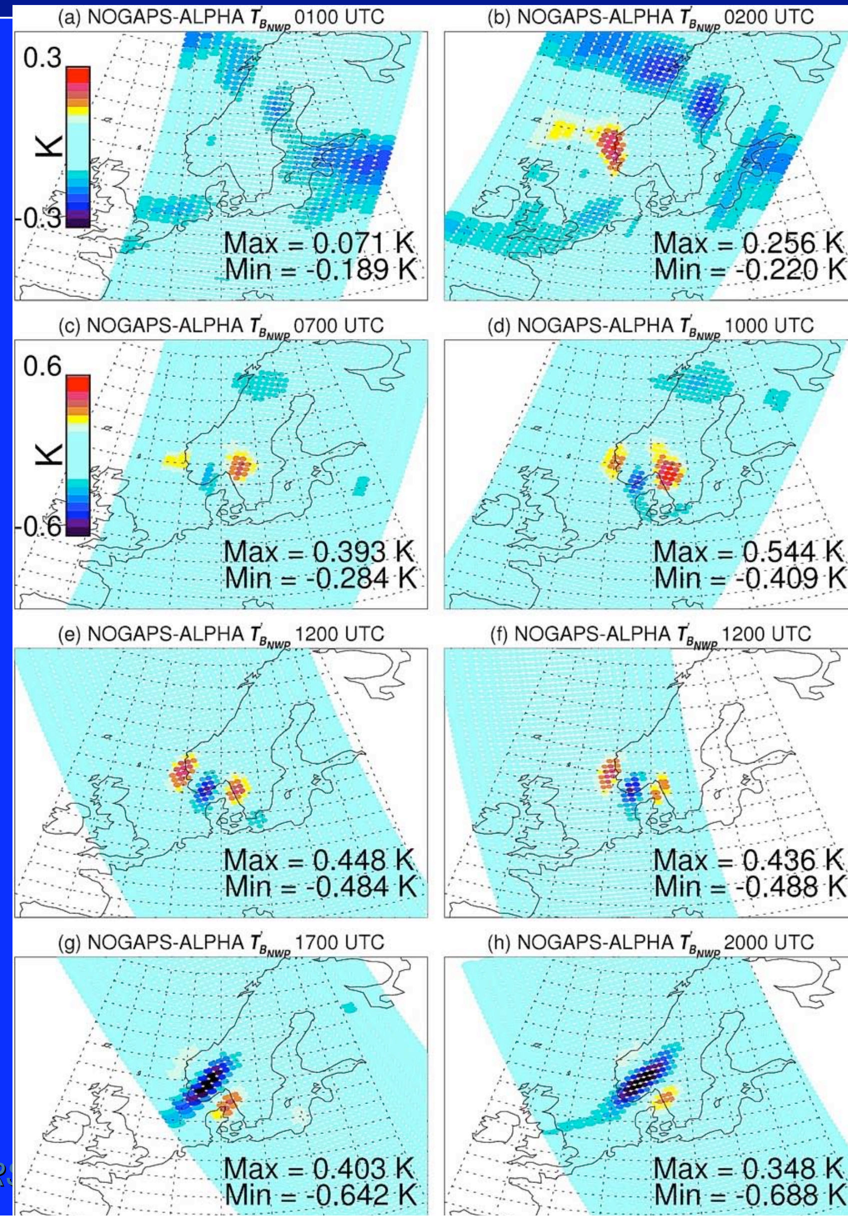
Time Evolution

AMSU-A on 4 Satellites (8 overpasses per day)

AMSU-A Observations



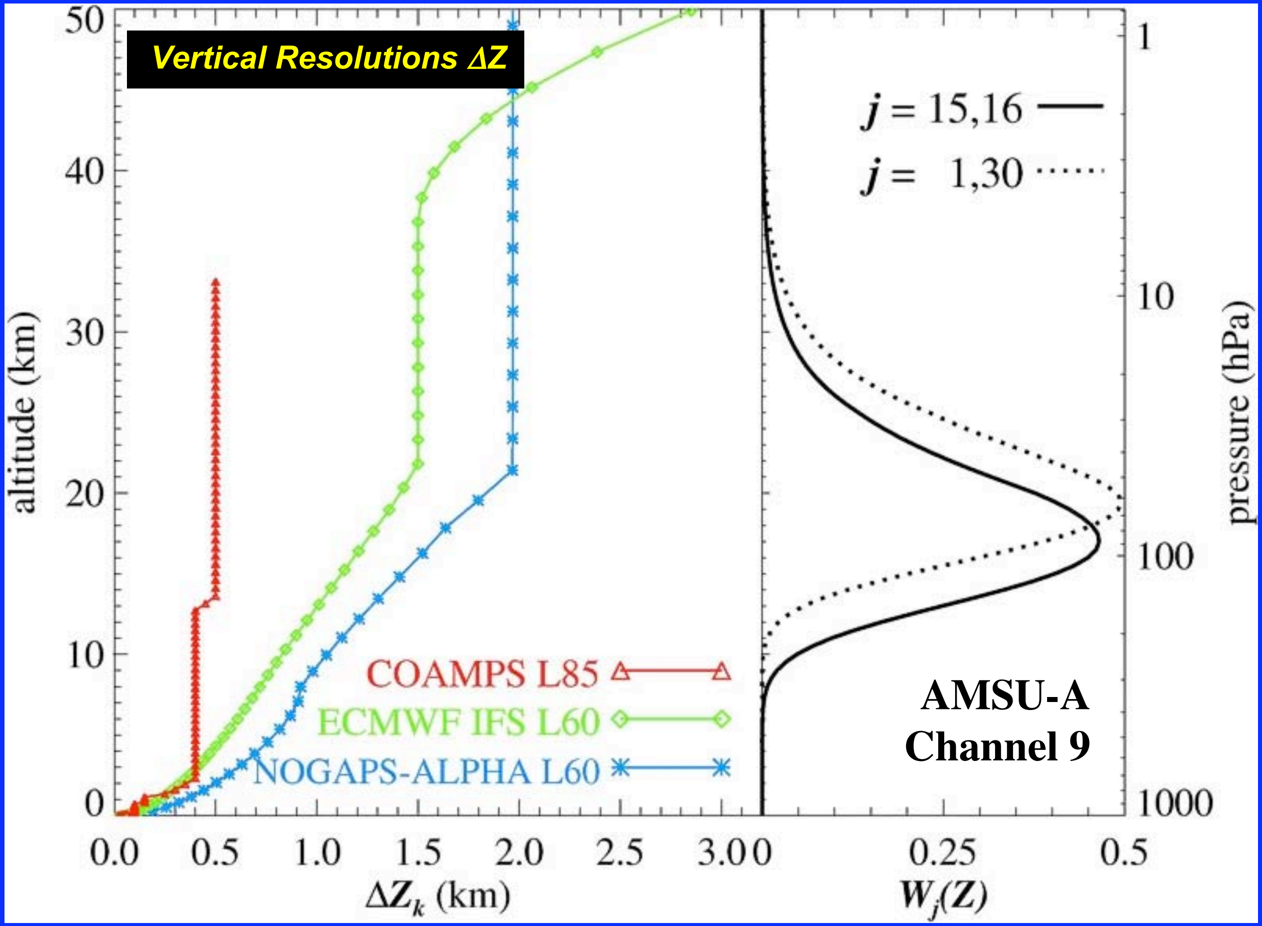
Forward-Modeled NOGAPS-ALPHA



Very High Resolution Numerical Weather Prediction (NWP) Model Runs

Science Team Meeting October 9-12

NWP Model	Resolution	$\Delta\phi$ (Δx)	p_{TOP} (z_{TOP})	Vertical Coordinate
ECMWF IFS	T_L511 L60	0.35º (~40km)	0.1 hPa (~65 km)	hybrid σ-p
NOGAPS-ALPHA	T239 L60	0.5º (~55 km)	0.005 hPa (~85 km)	hybrid σ-p
COAMPS ®	169x169 L85	30x30 & 10x10 km^2 (nest)	(~33 km)	σ

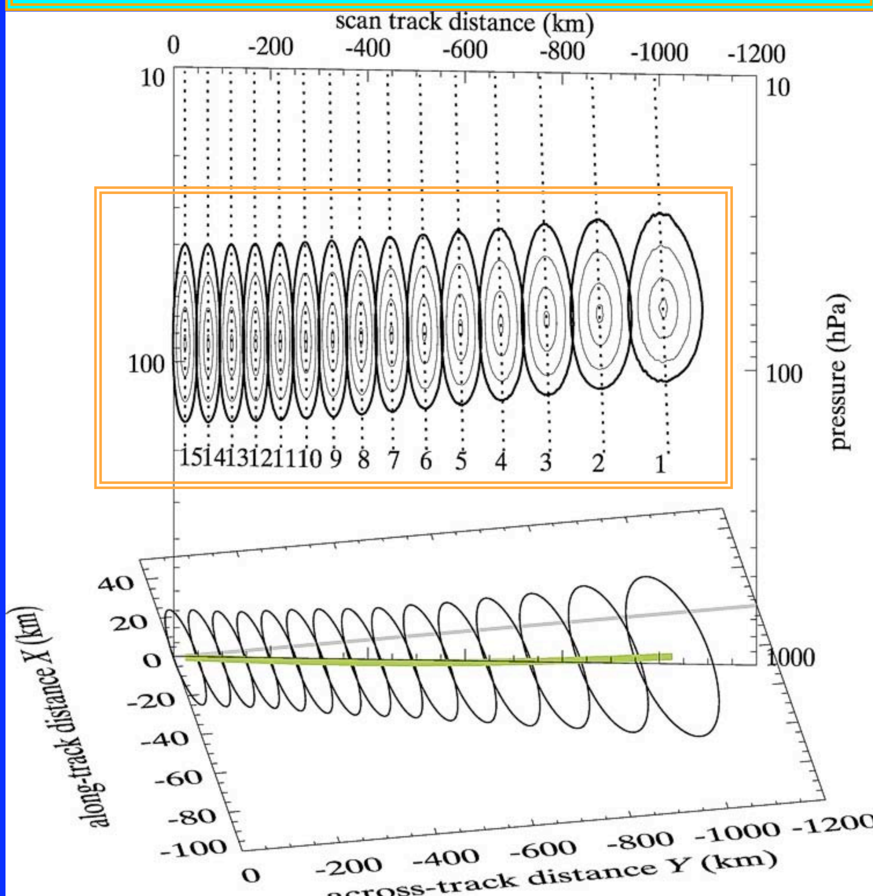


3D Temperature Weighting Functions From AMSU-A Channel 9

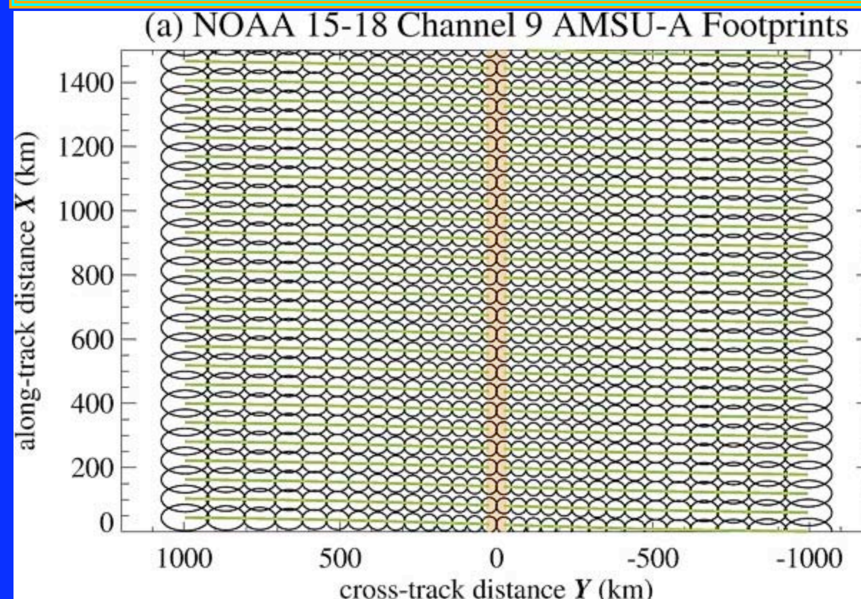
$$T_B(X_j,Y_J,Z_j) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{0}^{Z_{sat}} \boxed{W_j(X-X_j,Y-Y_J,Z-Z_j)}\, T(X,Y,Z)\,dX\,dY\,dZ$$

Brightness temperature (microwave radiance) = *3D AMSU-A Measurement Weighting Function* ⊗ *Atmospheric temperature*

2D Cross Sections in (Y,Z) Plane



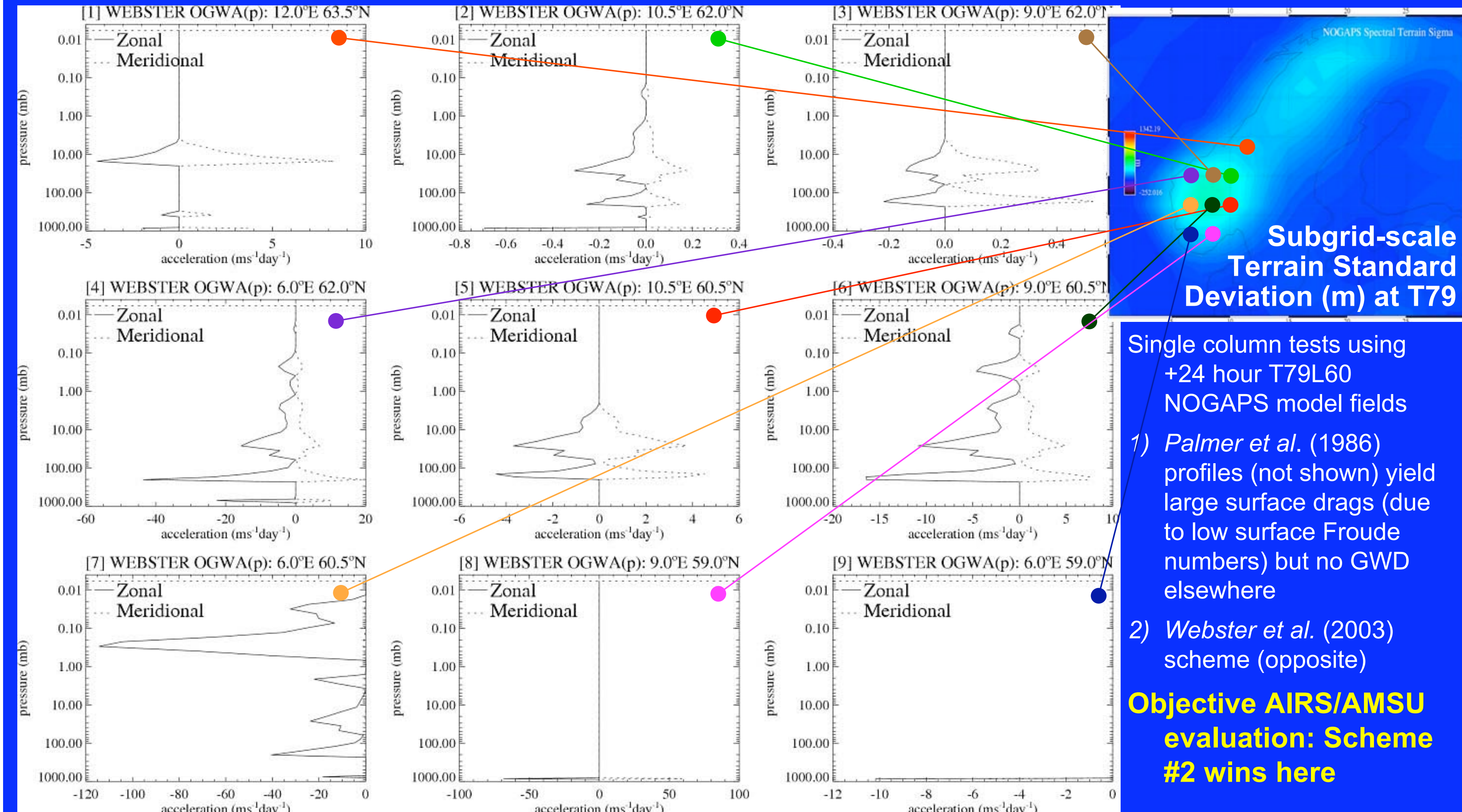
Horizontal "Footprints" (X,Y) Plane



$(\Delta X,\Delta Y)$~50-150km, ΔZ~8km

Suggests AMSU-A Channel 9 Radiances Might Resolve Long Wavelength GWs (λ_Y>150km, λ_Z>10 km)

Objective Validation of Subgrid-scale Orographic Gravity Wave Drag Schemes



Single column tests using +24 hour T79L60 NOGAPS model fields

1) *Palmer et al.* (1986) profiles (not shown) yield large surface drags (due to low surface Froude numbers) but no GWD elsewhere

2) *Webster et al.* (2003) scheme (opposite)

Objective AIRS/AMSU evaluation: Scheme #2 wins here